APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. $x10^{-3}$	NFPA Classification N_h	N_f	N_r	Flash Point ° F	Boiling Point ° F
Acetaldehyde	24	10.5	2	4	2	-38	70
Acetic Acid	14	5.6	2	2	1	103	245
Acetic Anhydride	24	7.1	2	2	1	129	284
Acetone	16	12.3	1	3	0	-4	133
Acetone Cyanohydrin	24	11.2	4	1	2	165	248
Acetonitrile	24	12.6	2	3	0	42	179
Acetyl Chloride	24	2.5	3	3	2	40	124
Acetylene	40	20.7	1	4	3	Gas	-118
Acetyl Ethanolamine	14	9.4	1	1	1	355	305
Acetyl Peroxide	40	6.4	1	2	4	—	[4]
Acetyl Salicylic Acid	—	8.9	1	1	0	—	—
Acetyl Tributyl Citrate	4	10.9	—	1	0	400	343[1]
Acrolein	24	11.8	3	3	2	-15	125
Acrylamide	14	9.5	2	1	1	—	257[1]
Acrylic Acid	24	7.6	3	2	2	122	287
Acrylonitrile	24	13.7	4	3	2	32	171
Allyl Alcohol	16	13.7	3	3	0	70	206
Allylamine	16	15.4	3	3	1	-20	128
Allyl Bromide	16	5.9	3	3	1	30	160
Allyl Chloride	29	9.7	3	3	1	-25	113
Allyl Ether	24	16.0	3	3	2	20	203
Aluminum Chloride	24	[2]	3	0	2	—	[3]
Ammonia	4	8.0	3	1	0	Gas	-28
Ammonium Nitrate	29	12.4[7]	2	0	3	—	410
Amyl Acetate	16	14.6	1	3	0	60	300
Amylacetate	16	14.4	1	3	0	77	300
Amyl Nitrate	24	11.5	2	2	0	118	306-315
Aniline	14	15.0	3	2	0	158	364
Barium Chlorate	24	[2]	0	1	2	—	—
Barium Stearate	4	8.9	0	1	0	—	—
Benzaldehyde	24	13.7	2	2	0	145	355
Benzene	16	17.3	2	3	0	12	176
Benzoic Acid	4	11.0	2	1	0	250	482
Benzyl Acetate	4	12.3	1	1	0	195	417
Benzyl Alcohol	4	13.8	2	1	0	200	403
Benzyl Chloride	14	12.6	2	2	1	153	354
Benzyl Peroxide	40	12.0	1	3	4	—	—
Bisphenol A	14	14.1	2	1	1	175	428
Bromine	1	0.0	4	0	0	—	—
Bromobenzene	14	8.1	2	2	0	124	313
o-Bromotoluene	10	8.5	2	2	0	174	359
1,3-Butadiene	24	19.2	2	4	2	Gas	24
Butane	21	19.7	1	4	0	Gas	31
Butanol (n-butyl alcohol)	16	14.3	1	3	0	84	243
1-Butene	21	19.5	1	4	0	Gas	21
Butyl Acetate	16	12.2	1	3	0	72	260
Butyl Acrylate	24	14.2	2	2	2	118	293
n-Butylamine	16	16.3	2	3	0	10	172
Butyl Bromide	16	7.6	2	3	0	65	215
Butyl Chloride	16	11.4	2	3	0	15	170

APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. $\times 10^{-3}$	NFPA Classification N_h	N_f	N_r	Flash Point °F	Boiling Point °F
2,3-Butylene Oxide	24	14.3	2	3	2	5	149
Butyl Ether	16	16.3	2	3	0	77	286
t-Butyl Hydroperoxide	40	11.9	1	4	4	80	—
Butyl Nitrate	29	11.1	1	3	3	97	277
t-Butyl Peracetate	40	10.6	2	3	4	<80	[4]
t-Butyl Perbenzoate	40	12.2	1	3	4	>190	[4]
t-Butyl Peroxide	29	14.5	1	3	3	64	176
Calcium Carbide	24	9.1	1	1	2	—	—
Calcium-Stearate[6]	4	—	0	1	0	—	—
Carbon Disulfide	16	6.1	2	3	0	-22	115
Carbon Monoxide	16	4.3	2	4	0	Gas	-314
Chlorine	1	0.0	3	0	0	—	—
Chlorine Dioxide	40	0.7	3	1	4	—	—
Chloroacetyl Chloride	14	2.5	3	0	1	—	222
Chlorobenzene	16	10.9	2	3	0	82	270
Chloroform	1	1.5	2	0	0	—	142
Chloro Methyl Ethyl Ether	14	5.7	2	1	1	—	—
1-Chloro 1-Nitroethane	40	3.53	—	2	3	133	344
o-Chlorophenol	10	9.2	3	2	0	147	347
Chloropicrin	29	5.8[7]	4	0	3	—	234
Chloropropane	21	10.1	2	4	0	-26	95
Chlorostyrene	24	12.5	2	1	2	—	—
Coumarin	24	12.0	2	1	2	—	554
Cumene	10	18.0	2	3	0	96	306
Cumene Hydroperoxide	40	13.7	1	2	4	175	[4]
Cyanamide	29	7.0	4	1	3	286	500
Cyclobutane	21	19.1	1	4	0	Gas	55
Cyclohexane	16	18.7	1	3	0	-4	179
Cyclohexanol	4	15.0	1	2	0	154	322
Cyclopropane	21	21.3	1	4	0	Gas	-29
DER* 331	14	13.7	—	—	—	485	878
Dichlorobenzene	14	8.1	2	2	0	151	356
1,2-Dichloroethylene	24	6.9	2	3	2	36	119
1,3-Dichloropropene	16	6.0	2	3	0	95	219
2,3-Dichloropropene	16	5.9	3	3	0	59	201
3,5-Dichloro Salicylic Acid	24	5.3	0	1	2	—	—
Dichlorostyrene	24	9.3	2	1	2	225	—
Dicumyl Peroxide	29	15.4	0	1	3	—	—
Dicycloentadiene	24	17.9	1	3	2	90	342
Diesel Fuel	10	18.7	0	2	0	100-130	315
Diethanolamine	14	10.0	1	1	0	342	514
Diethylamine	16	16.5	2	3	0	-9	134
m-Diethyl Benzene	10	18.0	2	2	0	133	358
Diethyl Carbonate	16	9.1	2	3	1	77	259
Diethylene Glycol	4	8.7	1	1	0	255	472
Diethyl Ether	21	14.5	2	4	1	-49	95
Diethyl Peroxide	40	12.2	—	4	4	[4]	[4]
Diisobutylene	16	19.0	1	3	0	23	214
Diisopropyl Benzene	4	17.9	0	2	0	170	401
Dimethyl Amine	21	15.2	3	4	0	Gas	45

* TRADEMARK OF THE DOW CHEMICAL COMPANY

APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. x10⁻³	NFPA Classification N_h	N_f	N_r	Flash Point °F	Boiling Point °F
2,2-Dimethyl Propanol	16	14.8	2	3	0	98	237
Dinitrobenzene	40	7.2	3	1	4	302	604
2,4-Dinitro Phenol	40	6.1	3	1	4	—	—
1,4-Dioxane	16	10.5	2	3	1	54	214
Dioxolane	24	9.1	2	3	2	35	165
Diphenyl Oxide	14	14.9	1	1	0	259	449
Dipropylene Glycol	4	10.8	0	1	0	280	449
Di-tert-Butyl Peroxide	40	14.5	3	2	4	70	—
Divinyl Acetylene	29	18.2	—	3	3	-4	183
Divinylbenzene	24	17.4	2	2	2	169	392
Divinyl Ether	24	14.5	2	3	2	-22	102
DOWANOL* PM	16	11.1	0	3	0	94	248
DOWICIL* 75	24	7.0	2	2	2	—	—
DOWICIL 200	24	9.3	2	2	2	—	—
DOWTHERM* A	4	15.5	1	1	0	255	495
DOWTHERM G	4	15.5	1	1	0	305	575
DOWTHERM J	10	17.8	1	2	0	145	358
DOWTHERM HT	4	—	1	1	0	355	650
DOWTHERM LF	4	16.0	1	1	0	260	507
DURSBAN*	14	19.8	1	2	1	81-110	—
Epichlorohydrin	24	7.2	3	2	2	88	239
Ethane	21	20.4	1	4	0	Gas	-128
Ethanolamine	4	9.5	2	2	0	185	342
Ethyl Acetate	16	10.1	1	3	0	24	171
Ethyl Acrylate	24	11.0	2	3	2	50	211
Ethyl Alcohol	16	11.5	0	3	0	55	173
Ethylamine	21	16.3	3	4	0	0	62
Ethyl Benzene	16	17.6	2	3	0	70	277
Ethyl Benzoate	4	12.2	1	1	0	190	414
Ethyl Bromide	21	5.6	2	1	0	—	100
Ethylbutylamine	16	17.0	3	3	0	64	232
Ethyl Butylcarbonate	14	10.6	2	2	1	122	275
Ethyl Butyrate	16	12.2	0	3	0	75	248
Ethyl Chloride	21	8.2	2	4	0	-58	54
Ethyl Chloroformate	16	5.2	—	3	1	61	201
Ethylene	24	20.8	1	4	2	Gas	-155
Ethylene Carbonate	14	5.3	2	1	1	290	351
Ethylenediamine	10	12.4	3	2	0	104	241
Ethylene Dichloride	16	4.6	2	3	0	56	183
Ethylene Glycol	4	7.3	1	1	0	232	387
Ethlene Glycol Dimethyl Ether	16	11.6	2	3	0	29	174
Ethylene Glycol Monoacetate	4	8.0	0	1	0	215	357
Ethylenimine	29	13.0	3	3	2	-20	132
Ethylene Oxide	29	11.7	2	4	3	0	51
Ethyl Ether	21	14.4	2	4	1	-49	95
Ethyl Formate	16	8.7	2	3	0	-4	130
2-Ethylhexanal	14	16.2	2	2	1	112	325
1,1-Ethylidene Dichloride	16	4.5	2	3	0	22	138
Ethyl Mercaptan	21	12.7	2	4	0	0	95
Ethyl Nitrate	40	6.4	2	3	4	50	190

*TRADEMARK OF THE DOW CHEMICAL COMPANY

APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. x10⁻³	NFPA Classification			Flash Point ° F	Boiling Point ° F
			N_h	N_f	N_r		
Ethyl Propyl Ether	16	15.2	1	3	0	<-4	147
p-Ethyl Toluene	10	17.7	—	2	0	108	324
Fluorine	29	—	4	0	3	—	-310
Fluorobenzene	24	13.4	—	3	0	5	185
Formaldehyde	24	8.0	2	4	0	Gas	-3
Formic Acid	4	3.0	3	2	0	156	213
Fuel Oil #1 to #6	10	18.7	0	2	0	100-150	304-574
Furan	21	12.6	1	4	1	32	88
Gasoline	16	18.8	1	3	0	-45	100-400
Glycerine	4	6.9	1	1	0	390	554
Glycolonitrile	14	7.6	1	1	1	—	—
Heptane	16	19.2	1	3	0	25	209
Hexachlorobutadiene	14	2.0	2	1	1	—	410
Hexachloro Diphenyl Oxide	29	5.5	2	1	1	—	446[1]
Hexanal	16	15.5	2	3	1	90	268
Hexane	16	19.2	1	3	0	-7	156
Hydrazine (anhydrous)	24	7.7	3	3	2	100	236
Hydrogen	21	51.6	0	4	0	Gas	-422
Hydrogen Cyanide	29	10.3	4	4	2	0	79
Hydrogen Peroxide (35%)	24	[2]	2	0	2	—	—
Hydrogen Sulfide	21	6.5	3	4	0	Gas	-76
Hydroxylamine	29	3.2	1	3	3	[4]	158
Hydroxy Ethyl Acrylate	14	8.9	2	1	2	154	375
Hydroxy Propyl Acrylate	14	10.4	2	1	2	149	375
Isobutane	21	19.4	1	4	0	Gas	11
Isobutyl Alcohol	16	14.2	1	3	0	82	225
Isobutylamine	16	16.2	2	3	0	15	150
Isobutylchloride	16	11.4	2	3	0	<70	156
Isopentane	21	21.0	1	4	0	<-60	82
Isoprene	21	18.9	2	4	1	-65	93
Isopropanol	16	13.1	1	3	0	53	181
Isopropenyl Acetylene	24	—	2	4	2	<19	92
Isopropyl Acetate	16	11.2	1	3	0	35	194
Isopropylamine	21	15.5	3	4	0	-35	89
Isopropyl Chloride	21	10.0	2	4	0	-26	95
Isopropyl Ether	16	15.6	2	3	1	-18	156
Jet Fuel A & A-1	10	21.7	0	2	0	110-150	—
Jet Fuel B	16	21.7	1	3	0	-10 to +30	—
Kerosene	10	19.8	0	2	0	100-162	304-574
Lauryl Bromide	4	12.9	1	1	0	291	356
Lauryl Mercaptan	4	16.8	2	1	0	262	289
LORSBAN* 4E	14	3.0	1	2	1	85	165
Lauryl Peroxide	40	15.0	0	1	4	—	—
Lube Oil	4	19.0	0	1	0	350-400	—
Magnesium	14	10.6	0	1	1	—	—
Maleic Anhydride	14	5.9	3	1	1	215	396
Methacrylic Acid	24	9.3	3	2	2	171	316
Methane	21	21.5	1	4	0	Gas	-259
Methyl Acetate	16	8.5	1	3	0	14	140
Methylacetylene	40	20.0	2	4	2	Gas	-10

*TRADEMARK OF THE DOW CHEMICAL COMPANY

APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. $\times 10^{-3}$	NFPA Classification			Flash Point °F	Boiling Point °F
			N_h	N_f	N_r		
Methyl Acrylate	24	18.7	2	3	2	27	176
Methyl Alcohol	16	8.6	1	3	0	52	147
Methylamine	21	13.2	3	4	0	Gas	21
Methyl Amyl Ketone	10	15.4	1	2	0	102	302
Methyl Borate	16	—	2	3	1	< 80	156
Methyl Carbonate	16	6.2	2	3	1	66	192
Methylcellulose (bag storage)	10	6.5	0	1	0	—	—
Methyl Chloride	21	5.5	2	4	0	-50	-11
Methyl Chloroacetate	14	5.1	2	2	1	135	266
Methylcyclohexane	16	19.0	2	3	0	25	214
Methyl Cyclopentadiene	14	17.4	1	2	1	120	163
Methylene Chloride	4	2.3	2	1	0	—	104
Methyl Ether	21	12.4	2	4	1	Gas	-11
Methyl Ethyl Ketone	16	13.5	1	3	0	16	176
Methyl Formate	21	6.4	2	4	0	-2	90
Methylhydrazine	24	10.9	3	3	2	17	190
Methyl Isobutyl Ketone	16	16.6	2	3	0	64	244
Methyl Mercaptan	21	10.0	2	4	0	—	42
Methyl Methacrylate	24	11.9	2	3	2	50	212
2-Methylpropenal	24	15.4	3	3	2	35	154
Methyl Vinyl Ketone	24	13.4	3	3	2	20	177
Mineral Oil	4	17.0	0	1	0	380	680
Mineral Seal Oil	4	17.6	0	1	0	275	480-680
Monethanolamine	4	9.6	2	1	0	200	338
Monochlorobenzene	16	11.3	2	3	0	82	270
Naphtha, V.M. & P. Regular	16	18.0	1	3	0	28-85	212-320
Naphthalene	14	16.7	2	2	0	174	424
Nitrobenzene	24	10.4	3	2	0	190	412
Nitrobiphenyl	14	12.7	2	1	0	290	626
Nitrichlorobenzene	29	7.8	3	1	1	261	457
Nitroethane	29	7.7	1	3	3	82	237
Nitroglycerine	40	7.8	2	2	4	[4]	[4]
Nitromethane	40	5.0	1	3	3	95	214
1-Nitropropane	29	9.7	1	3	1	96	268
p-Nitrotoluene	29	11.2	3	1	0	223	461
N-SERV*	10	15.0	2	2	1	102	300
Octane	16	20.5	0	3	0	56	258
t-Octyl Mercaptan	10	16.5	2	2	0	115	329
Oleic Acid	4	16.8	0	1	0	372	547
Pentamethylene Oxide	16	13.7	2	3	1	-4	178
Pentane	21	19.4	1	4	0	-40	97
Peracetic Acid	40	4.8	3	2	4	105	221
Perchloric Acid	29	[2]	3	0	3	—	397
Petroleum - Crude	16	21.3	1	3	0	20-90	—
Phenol	4	13.4	3	2	0	175	358
2-Picoline	14	15.0	2	2	0	102	262
Polyethylene	18	18.7	—	—	—	NA	NA
Polystyrene Foam	16	17.1	—	—	—	NA	NA
Polystyrene Pellets	10	—	—	—	—	NA	NA
Potassium	24	—	3	1	2	—	1418

*TRADEMARK OF THE DOW CHEMICAL COMPANY

APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. x10⁻³	NFPA Classification			Flash Point ° F	Boiling Point ° F
			N_h	N_f	N_r		
Potassium Chlorate	29	[2]	2	0	3	—	752
Potassium Nitrate	29	[2]	1	0	3	—	752
Potassium Perchlorate	24	[2]	1	0	2	—	—
Potassium Peroxide	24	[2]	3	0	2	—	—
Propanal	16	12.5	2	3	1	22	120
Propane	21	19.9	1	4	0	Gas	-44
1 3-Propanediemine	16	13.6	2	3	0	75	276
Propargyl Alcohol	29	12.6	3	3	3	97	239
Propargyl Bromide	40	13.6[7]	4	3	4	64	192
Proprionic Nitrile	16	15.0	4	3	1	36	207
Propyl Acetate	16	11.2	1	3	0	55	215
Propyl Alcohol	16	12.4	1	3	0	74	207
Propylamine	16	15.8	3	3	0	-35	120
Propylbenzene	16	17 3	2	3	0	86	319
Propylchloride	16	10.0	2	3	0	0	115
Propylene	21	19.7	1	4	1	Gas	-53
Propylene Dichloride	16	6.3	2	3	0	60	205
Propylene Glycol	4	9.3	0	1	0	210	370
Propylene Oxide	24	13.2	2	4	2	-35	94
Propyl Ether	16	15.7	1	3	0	70	194
Propyl Nitrate	29	7.4	2	4	3	68	231
Pyridine	24	5.9	2	3	0	68	239
Sodium	24	—	3	1	2	—	—
Sodium Chlorate	24	—	1	0	2	—	[4]
Sodium Dichromate	14	—	1	0	1	—	[4]
Sodium Hydride	24	—	3	3	2	—	[4]
Sodium Hydrosulfite	24	—	3	1	2	—	[4]
Sodium Perchlorate	24	—	2	0	2	—	[4]
Sodium Peroxide	24	—	3	0	2	—	[4]
Stearic Acid	4	15.9	1	1	0	385	726
Styrene	24	17.4	2	3	2	88	295
Sulfur	4	4.0	2	1	0	—	—
Sulfur Chloride	24	1.8	2	1	2[5]	245	280
Sulfur Dioxide	1	0.0	2	0	0	Gas	12
Tetrachlorobenzene	4	4.7	0	1	0	311	475
TELONE*II	16	3.2	2	3	0	83	220
TELONE* C-17	16	2.7	3	3	1	79	200
Toluene	16	17.4	2	3	0	40	231
Tributylamine	4	17.8	2	2	0	187	417
Trichlorobenzene	29	6.2	2	1	3	210	413
1 1,1-Trichloroethane	14	3.1	3	1	1	None	165
Trichloroethylene	4	2.7	2	1	0	None	188
1,2,3-Trichloropropane	10	4.3	3	2	0	180	313
Triethanolimine	14	10.1	2	1	1	385	650
Triethylaluminum	29	16.9	3	3	3	-63	381
Triethylamine	16	17.8	2	3	0	16	193
Triethylene Glycol	4	9.3	1	1	0	350	546
Triisobutylaluminum	29	18.9	—	3	3	32	238
Triisopropylbenzene	16	18.1	0	1	0	207	495
Trimethylaluminum	29	16.5	—	3	3	32	259

* TRADEMARK OF THE DOW CHEMICAL COMPANY

APPENDIX A
MATERIAL FACTORS (MF)

Compound	MF	Hc BTU/lb. x10[-3]	NFPA Classification			Flash Point °F	Boiling Point °F
			N_h	N_f	N_r		
Trimethylamine	21	10.1	2	4	0	Gas	38
Tripropylamine	10	17.8	2	2	0	105	313
Vinyl Acetate	24	9.7	2	3	2	18	161
Vinyl Acetylene	40	19.5	—	4	3	—	41
Vinyl Allyl Ether	24	15.5	2	3	2	68	153
Vinyl Butyl Ether	24	15.4	2	3	2	15	202
Vinyl Chloride	21	8.0	2	4	1	Gas	7
Vinyl Cyclohexene	24	19.0	0	3	2	61	266
Vinyl Ethyl Ether	24	14.0	2	4	2	-50	96
Vinylidene Chloride	24	4.2	2	4	2	-19	89
Vinyl Toluene	14	17.5	2	2	1	120	334
Xylene	16	17.6	2	3	0	81	292
Zinc Chlorate	24	[2]	2	1	2	—	—
Zinc Stearate[8]	—	10.1	0	1	0	530	—

Footnotes:

The net Heat of Combustion (H_c) is the value obtained when the water formed in the combustion is considered to be in the vapor state. When H_c is given in Kcal/gm mole it can be converted to Btu/lb by multiplying by 1800 and dividing by molecular weight.

[1]Vacuum distillation [2]Material oxidized to higher level of oxidation

[3]Sublimes [4]Explodes on heating [5]Decomposes in water [6]MF is packaged material

[7]Hc equivalent to six times the heat of decomposition (Hd) [8]Evaluate as a DUST

APPENDIX B

DETERMINATION OF MATERIAL FACTOR BY CALCULATION/TESTING

The **Material Factor** has only two components, flammability and reactivity, and represents the hazard of both. Once these two are established, the **Material Factor** can be determined, as described in the text.

The selection of the significant material for determining the **Material Factor** can be a problem. Pure materials are straightforward. Problems arise when the process has a mixture of materials, particularly in batch reactors where many sequential reactions are done.

For example, in a batch process, where the composition changes during the batch cycle, it will be valid to select the worst condition which normally occurs during the cycle.

If there is a mixture of materials in a **Process Unit** with **MF** (Material Factor) of 10, 16 and 24, 16 should not immediately be used as the key **MF** since the mixture "Hazard" is not necessarily the material with an **MF** of 16.

The best way to determine the **MF** of the mixture is to obtain the flash point, boiling point (initial) and DTA/DSC exotherm peak temperature of the mixture, and to use them to enter Table I of the text.

The Reactive Chemicals program requires that the flash point, DTA/DSC and other pertinent data be obtained before scale-up. Therefore, these data should be available. As an interim temporary measure, if it is an absolute certainty that there is no reaction between components of a mixture, one can estimate the flash point, etc., using certain chemical engineering approximations, provided the components are chemically homologous. Example B illustrates such an approximation estimate:

Example B

Matl.	Wt.%	MW	Mol. Frac.	Fl. Pt. °F	BP °F	DTA °C	Matl. Factor
Styrene (STY)	20	104	.22	90	295	220	24
Ethylbenzene (EB)	40	106	34	59	277	400	16
Diethylbenzene (DEB)	40	134	.44	133	358	400	10

Calculations

Matl.	Rel. Vap. Press.	RVP X Mol. Frac.
STY	.55	.121
EB	1.00	.340
DEB	.077	.034
		.495

Since there is no interreactivity, a rough estimate of the mixture flash point, (initial) boiling point, and DSC/DTA can be made on the principle that vapor pressure and reaction rate double about every 20 C° for most materials at temperatures of interest. This is done as follows:

Flash Point: Using EB as the key, calculate relative vapor pressure (RVP). Styrene has a 31°F (17°C) higher flash point and is 0.5 (17/20) = .55 in RVP. DEB similarly is 0.5 (133-59/20) = 077. Adding the RVP x Mol. Frac. for the three components, the mixture RVP is .495, so the flash point is 20 x log .495/log .5 = 20.3°C, x 1.8 = 37°F higher than the key; namely 37 + 59 = 96°F.

(Initial) Boiling Point: Since all boiling points are above 100°F, the mixture will boil above 100°F, which is all that is needed here. For a flash point of 96°F and a boiling point above 100°F, N_f = 3 (Table I, page 13).

DSC/DTA: Using the lowest DSC/DTA (220°C) and noting the Mole Fracture one would expect the reaction to proceed at .22 of the rate of the pure component. The temperature for the same rate would be higher by 20 x log .22/log .5 = 44°C, + 220 = 264°C estimated DTA peak for the mixture, which therefore has a N_r = 2. (See DETERMINE MATERIAL FACTOR section.)

Material Factor: From N_f = 3 and N_r = 2, Table I gives MF = 24 at temperatures up to 140°F (60°C). The **Material Factor** section provides adjustment for temperatures above 140°F.

This **Material Factor** would reflect a realistic hazard of the mixture. The MF of a mixture is usually the highest MF among the components present in a significant concentration, say, five percent or so.

Some examples of Material Factor application are:

1. ETHYLENE AND CHLORINE IN AN EDC REACTOR TO PRODUCE EDC. MF should be for EDC and not ethylene or chlorine. Because the reaction is very fast between the ethylene or chlorine. Because the reaction is very fast between the ethylene and chlorine being sprayed into liquid EDC (ethylene dichloride), the reactor contains only EDC. The hazard is EDC in the reactor.

2. ETHANE CRACKED IN A FURNACE TO MAKE ETHYLENE. MF should be for ethylene. The most likely leak of contents is a mixture of ethane and ethylene, with the ethylene content significant enough to make the mixture much like ethylene in its reactivity.

3. CONTINUOUS BENZENE ALKYLATION REACTOR. The feed streams to the reactor are ethylene (MF = 24) and benzene (MF + 16), while the bulk of inventory in the reactor is ethyl benzene (MF = 16). There is a minimum of unreacted ethylene present in the reactor. The recommended material factor of use is 16. Although this process involves the potential for release of an ethylene vapor cloud external to the reactor, there is no connection between this and penalty factors applied for conditions in the reactor. It would be wise to consider something in the ethylene feed system as a separate Process Unit and calculate the F&EI for the feed system Process Unit to determine the worst case.

4. POLYOL REACTOR (BATCH PROCESS). The initial charge to the reactor is glycerine (MF = 4) Propylene oxide (PO) (MF = 21) and/or ethylene oxide (EO) (MF = 29) are added progressively during the batch and react with the glycerine to form the polyol (MF = 4). When EO alone is used, it reacts relatively quickly so that there are only small amounts of unreacted EO present in the reactor at any time; hence, the reactor MF = 4. However, the PO reaction is slower and there may be up to about 15% of unreacted PO present at some stage. The suggested material factor, then, for the F&EI calculation is the factor for the worst case reaction mixture containing 15% PO (MF = 24).

   This is a typical case where it is not appropriate to take a weighted average of factors for individual components in determining the factor for the mixture. This is due to the wide disparity in the properties of components and the high molecular weight of the polyol. It is necessary to consider the actual properties of the mixture which are equivalent to N_f = 3 and N_r = 2, for a material factor of 24. This compares with a value of about 6.6 which would be wrongly obtained as a weighted average factor. If the properties of the mixture are not known, the approach taken in 3. above may be appropriate while awaiting results of reactive chemicals testing of the mixture.

5. ELECTROLYTIC PRODUCTION OF CHLORINE PRESENTS A TYPICAL APPROACH. The process is endothermic and not theoretically hazardous; the hazards present are due to the presence of flammable hydrogen and reactive chlorine. The MF for hydrogen would be correct for this evaluation, as the MF for hydrogen is the higher.

6. WHEN FEEDING TWO REACTANTS CONTINUOUSLY, SUCH AS IN BURNERS, consider the "burner-type" reactor. An example is an HCl (hydrogen chloride) synthesis reactor, which, as a Process Unit reacts hydrogen with chlorine but normally contains only HCl, a completely non-reactive and non-combustible gas (MF = 1). However, the slightest upset can result in flameouts, and reaction ceases, resulting in the Process Unit filling with reactants. The explosion hazards of HCl synthesis reactors are so well known that they are always provided with explosion relief. MF should be based on the higher MF of the two reactants, hydrogen (MF = 21) and chlorine (MF = 14); that is, the MF should be 21.

   Fired boilers and furnaces are subject to flameout and explosive re-ignition (of the reactants, fuel and air). They should be treated similarly to the example in the previous paragraph.

7. If a mixture is mostly water, consider carefully the condition of the water in determining the "material factor" to avoid an unrealistically low value. For example, water saturated with butadiene will have a true flash point equal to that of butadiene, but will not have a DTA/DSC exotherm. The vapor above such water is mostly butadiene. N_r = O and N_f = 4; therefore, Mf = 21 for the vapor space.

In summary, the **Process Unit** should be examined over its cycle of operation for the most hazardous state. The most hazardous state is when the worst possible materials may escape from or exist in the process equipment during normal starting up, operating or shutting down.

APPENDIX C

BASIC PREVENTATIVE AND PROTECTIVE FEATURES

Many of the features below should be provided regardless of the type of operation or the magnitude of the **Fire and Explosion Index**. When they are not provided, the existing hazard exposure may be greater than the F&E Index indicates.

This list is not all-inclusive as other features may be needed, depending upon the specific installation.

A. Adequate water supply for fire protection. This is determined by multiplying its water demand by the length of time that the worst possible fire can be expected to last. The supply deemed adequate will vary with different authorities and may range from enough for a two-hour fire to enough for one lasting eight hours. (See Loss Prevention Principle [LPP] 4.5)

B. Structural design of vessels, piping, structural steel, etc.

C. Overpressure relief devices. (See LPP 14.3)

D. Corrosion resistance and/or allowances.

E. Segregation of reactive materials in process lines and equipment.

F. Electrical equipment grounding.

G. Safe location of auxiliary electrical gear (transformers, breakers, etc.) (See LPP 3.5)

H. Normal protection against utility loss (alternate electrical feeder, spare instrument air compressor, etc.)

I. Compliance with various applicable codes (ASME, ASTM, ANSI, Building Codes, Fire Codes, etc.)

J. Fail-safe instrumentation. (See LPP 15.2)

K. Access to area for emergency vehicles and exits for personal evacuation. (See LPP 2.3)

L. Drainage to handle probable spills safely plus firefighting water from hose nozzles and sprinkler heads and/or chemicals. (See LPP 2.4)

M. Insulation of hot surfaces that heat to within 80% of the autoignition temperature of any flammable in the area.

N. Adherence to the National Electrical Code. The Code should be followed except where variances have been requested/approved. (See LPP 3.1)

O. Limitation of glass devices and expansion joints in flammable or hazardous service. Such devices are not permitted unless absolutely essential. Where used, they must be registered and approved by the production manager and installed in accordance with Dow standards and specifications. (See LPP 6.9)

P. Building and equipment layout. Separation of high-hazard area must be recognized especially as it relates to both property damage and interruption of business. Separation of tanks must be at least in accordance with NFPA No. 30 (See LPP 2.2)

Q. Protection of pipe racks and instrument cable trays as well as their supports from exposure to fire. (See LPP 3.2)

R. Provision of accessible battery limit block valves.

S. Cooling tower loss prevention and protection. (See LPP 6.1)

T. Protection of fired equipment against accidental explosion and resultant fire. (See LPP 13.1 through 13.5)

U. Electrical classification. Division 2 electrical equipment will be required for outside flammable liquid handling where congestion is minimal and natural ventilation is unobstructed. Division 1 equipment is required only for special chemicals and/or special building or process handling conditions, or where ventilation is inadequate. (See LPP 3.1)

V. Process control rooms shall be isolated by one hour fire walls from process control laboratories and/or electrical switch-gear and transformers. (See LPP 12.2)

W. A process review shall determine a need for reactive chemicals testing. (See Guidelines For A Reactive Chemicals Program)

APPENDIX D

LOSS PREVENTION CHECKLIST

Scope

This checklist outlines most engineering topics needing consideration for possible loss prevention requirements. Such topics include location, buildings, sprinklers, electrical, sewers, storage, raw materials, computers, material handling, machinery, process, general safety equipment etc.

Introduction

This checklist is intended as a guide for use when assessing the fire hazards and reviewing the loss prevention requirements of a chemical plant. It may also be of particular advantage in planning new facilities. No such checklist can ever be entirely complete or meet the needs of every situation. Care should be taken in using such a list to make sure that other pertinent items not included here are not overlooked.

Location

A. Plant layout: separation of units per hazard evaluation
B. Accessibility
C. Traffic — vehicular and pedestrian
D. Parking areas — entrances, exits, drainage, lighting, enclosures
E. Clearances — buildings for railroad traffic and vehicles (overhead turnarounds)
F. Drainage, impounding areas
G. Road locations, markings
H. Entrances, exits — pedestrian, vehicular, railroad
I Ignition sources — furnace location, flare stacks, boilers, burner management
J Prevailing wind
K. Underground utility conduits
L. Flood control or protection
M Loading/unloading facilities, avoid using main traffic area for this activity

Buildings

A. Basic non-combustible construction
B. Wind pressure, snow loads, floor loads, earthquake design
C. Roof material, anchorage
D. Roof vents and drains, smoke dispersal
E. Stairwells, ramps, lighting
F. Elevators and dumbwaiters
G. Fire walls, openings, fire doors
H. Explosion relief, blast design
I. Exits — fire escapes, identification, safety tread
J. Record storage
K. Ventilation — fans, blowers, air conditioning, scrubbing of toxic vapors, location of exhaust inlets, smoke and heat ventilation dampers, fire curtains
L. Lightning protection, structural and equipment grounding for electrical discharges
M. Building heaters (Division 1 or 2 or ordinary areas), vents
N. Locker rooms including need for separate lockers for work and street clothes, required number of each and air changes
O. Building drainage — inside and out, properly trapped
P. Structural steel and equipment fireproofing
Q. Access ladders to roofs and outside level, escape ladders, fire escapes
R. Bearing capacity of subsoil
S. Heat and smoke detection
T. Elevation — floor plain restrictions
U. Wheel load on overhead crane

Fire Protection

A. Water supply including secondary supplies, pumps, reservoirs and tanks
B. Mains — adequate looping, cathodic protection, coated and wrapped when needed, sectional valves
C. Hydrants — location, spacing, monitors
D. Automatic sprinklers — occupancy classification, wet systems, dry systems, deluge systems
E. Standpipes and tanks
F. Type, size, location and number of fire extinguishers needed
G. Fixed automatic extinguishing systems, CO_2, foam, dry powder, Halon
H. Special fire protection systems — rise in temperature alarms, sprinkler system flow alarms, photoelectric smoke and flame alarms, snuffing steam
I. Piping system — materials of construction, no cast iron if explosion is possible

Electrical

A. Electrical hazard classifications, intrinsically safe
B. Accessibility of critical circuit breakers and switchgear
C. Polarized outlets and grounded systems
D. Switches and breakers for critical equipment and machinery
E. Lighting — Division 1 or 2 or ordinary areas, light intensity, approved equipment, emergency lights
F. Telephones and intercoms — Division 1 or 2 or ordinary areas
G. Type of electrical distribution system — voltage, grounded or ungrounded, overhead, underground
H. Conduit, raceways, enclosures, corrosion considerations
I. Motor and circuit protection
J. Transformer location and types
K. Fail safe control devices protection against automatic restarting
L. Preferred or backup busses for critical loads
M. Key interlocks for safety and proper sequencing, duplicate feeders
N. Lightning protection
O. Exposure of cable trays to fire damage
P. Uninterruptible power (UPS) and emergency power system
Q. Requirements for equipment grounding, methods and frequency of testing

Sewers

A. Chemical sewers — trapped, accessible cleanouts, vents, locations, disposal, explosion possibilities, trap tanks, forced ventilation, automatic flammable vapor detectors and alarms, freezing or ice blocks
B. Sanitary sewers — treatment, disposal, traps, plugs, cleanouts, vents
C. Storm sewers
D. Waste treatment, possible dangers from steam contamination including fire hazard from spills into streams and lakes
E. Drain trenches — open, buried, accessible cleanouts, presence of required baffles, exposure to process equipment
F. Ground water impairment prevention, air and surface water safeguards and proper disposal of waste.
G. Sewer drains connected to process drains?

Storage

A. General

1. Accessibility — entrances and exits, sizes
2. Sprinklered
3. Aisle space
4. Floor loading
5. Racks and spacing
6. Height of piles
7. Roof venting
8. Spill containment

B. Flammable liquids — gases, dusts and powders, fumes and mists

1. Closed systems
2. Safe atmospheres throughout system
3. Areas to be sprinklered or provided with water spray
4. Emergency vents, flame arrestors, relief valves, safe venting location including flares
5. Floor drains to chemical sewers properly trapped
6. Ventilation — pressurized controls, etc., and/or equipment
7. Tanks, bins, silos — underground, aboveground, safe distance separation, fireproof supports, dikes and drainage, inert atmospheres
8. Special extinguishing systems, explosion suppression — foam, dry chemicals, carbon dioxide
9. Dependable refrigeration systems for critical chemicals
10. Location of pumps, compressors, etc. away from spill potential
11. Weak roof seam construction on API tanks

Raw Materials

A. Danger of risk classification of material including shock sensitivity
B. Facilities for receiving and storing
C. Identification and purity tests
D. Provisions to prevent materials being placed in wrong tanks, tank overflow, etc.

Finished Products

A. Identification and labeling to protect the customer
B. Conformance with shipping regulations
C. Segregation of dangerous materials
D. Protection from contamination, especially in the filling of tank cars and tank trucks
E. Placarding of shipping vehicles
F. Routing of dangerous shipments
G. Data sheets for safety information for customers
H. Safe storage facilities, piling height
I. Safe shipping containers

Inert Gas Blanketing of All Flammable Products

A. Consider raw material, intermediates and products
B. Consider storage, material handling and processes

Materials Handling

A. Truck loading and unloading facilities
B. Railroad loading and unloading facilities
C. Industrial trucks and tractors — gasoline, diesel, liquefied petroleum gas and battery
D. Loading and unloading docks for rails, tank trucks and truck trailer — grounding system for flammable liquids
E. Cranes — mobile, capacity marking, overload protection, limit switches, inspection schedule
F. Warehouse area — floor loading and arrangement, sprinklers, height of piles, ventilation, smoke and heat detection
G. Conveyers and their location in production areas
H. Flammable liquid storage — paints, oils, solvents
I. Reactive or explosive storage — quantities, distance separation, limited access
J. Disposal of wastes — incinerators, air and water pollution safeguards
K. Spill control

Machinery

A. Accessibility, maintenance and operations
B. Remote emergency stop switches
C. Vibration monitoring/shutdown
D. Lubrication monitoring
E. Overspeed protection
F. Noise evaluation

Process

A. Chemicals — fire and health hazards (skin and respiratory), instrumentation, operating rules, maintenance, compatibility of chemicals, stability, labeling of pipelines and equipment, etc.
B. Critical pressures and temperatures
C. Relief devices and flame arrestors, properly registered
D. Coded vessels and suitable piping material
E. Methods for handling runaway reactions
F. Fixed fire protection systems — Co_2, foam, sprinkler deluge
G. Vessels properly vented, safe location, deadhead pump protection
H. Permanent vacuum cleaning systems
I. Explosion barricades and isolation
J. Inert gas blanketing systems — listing of equipment to be blanketed
K. Emergency shutdown valves and switches, location from critical area, action time for relays, emergency block valves
L. Fireproofing of structural steel beams and columns
M. Safety devices for heat exchange equipment — vents, valves and drains
N. Expansion joints, expansion loops for steam lines
O. Steam and electrical tracing — provision for relief of thermal expansion in heated lines
P. Insulation for personnel protection — hot process, steam lines and tracing — overheating protection of material in pipe
Q. Static grounding for vessels, piping and production equipment
R. Cleaning and maintenance of vessels and tanks — adequate manholes, platforms, ladders, cleanout openings and safe entry permit procedures
S. Provisions for corrosion control
T. Pipeline identification
U. Radiation problems including personal protection for firefighters — processes and measuring instruments containing radioisotopes, X-rays, etc.
V. Redundant critical instruments with alarms, fail safe operation
W. Glass devices
X. Critical instrument designation
Y. Fixed flammable gas detection system

Process Computers

A. Control Room

   1. Air handling — temperature, humidity, dust, etc.
   2. Location — ground floor preferred, non-combustible construction
   3. Floor covering — vinyl or laminated plastic to prevent static
   4. Space requirements for accessibility, no paper storage
   5. Lighting and power receptacles
   6. Fire protection — use CO_2 or Halon, smoke detectors

B. Power Wiring and Grounding

   1. Adequate power supply from special panel
   2. Dual sources of power
   3. Computer control system grounded at source, i.e. at step down transformer
   4. Control room junction boxes connected to building ground

C. Signal Wiring

   1. Field wiring terminated in a control junction box or other interface device
   2. Wiring protected by cable tray, metal wireway, conduit or run below raised floor
   3. Ribbon cables or similar type fragile cables run in separate enclosure from field cables

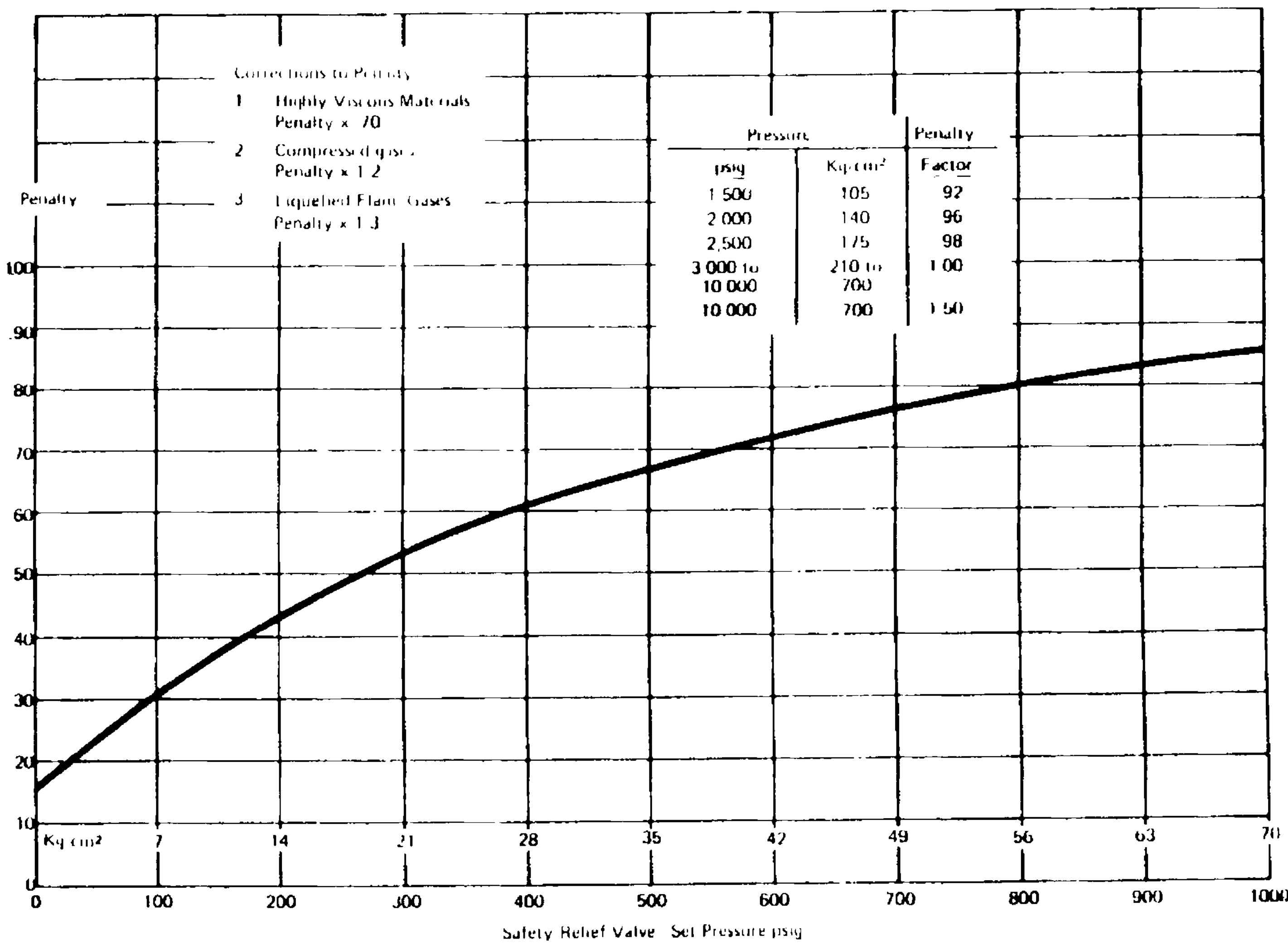
D. Control Systems

1. Fail safe conventions
2. Policies on parameter changes and manual control of outputs or input
3. Policies on control strategy changes and backup of current strategy
4. Documentation — inputs and outputs, operating discipline and control logic diagrams
5. Shutdown procedures for loss of utilities
6. Training
7. Alarm system
8. Regular audits
9. Control room integrity and location
10. Source of power for process controllers
11. Backup control systems

Safety Equipment, General

A. Dispensary and equipment
B. Ambulance
C. Fire truck
D. Emergency alarm system — alert, gas release, evacuate, etc.
E. Fire whistle and siren — departments, inside and outside
F. Snow removal and ice control equipment
G. Safety showers and eye wash fountains — operational alarms
H. Safety ladders and cages
I. Emergency equipment locations — gas masks, protective clothing, inside hose streams, stretchers, flash suits, self-contained breathing apparatus, etc.
J. Laboratory safety shields
K. Instruments — continuous, portable analyzers for flammable vapors and gases, oxygen, toxic vapors, etc.
L. Communications — emergency telephones, radio, public address systems, paging systems, safe location and continuous manning of communication center
M. Guards on rotating equipment
N. Combustion safeguards on furnaces, burner management system
O. Fuel gas shutoff valves
P. Spill/vapor release alarms
Q. Flange protectors on acid lines

Figure 2 — Pressure — Relief Valve Setting for Flammable and Combustible Liquids



Pressure psig	Pressure Kg/cm²	Penalty Factor
1 500	105	92
2 000	140	96
2,500	175	98
3 000 to 10 000	210 to 700	1 00
10 000	700	1 50

Figure 3 — Liquids or Gases in Process

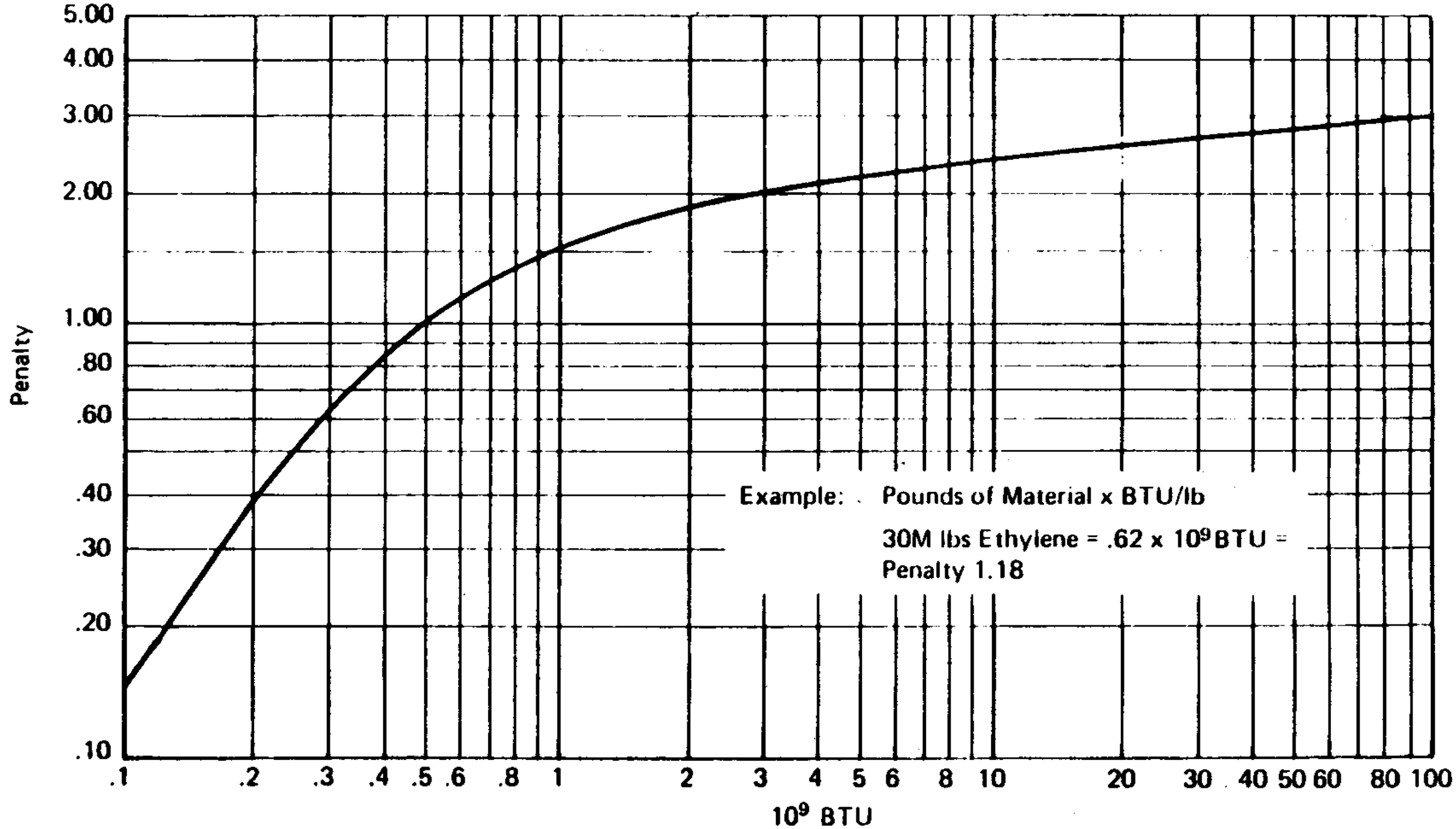


Figure 4 — Liquids or Gases in Storage

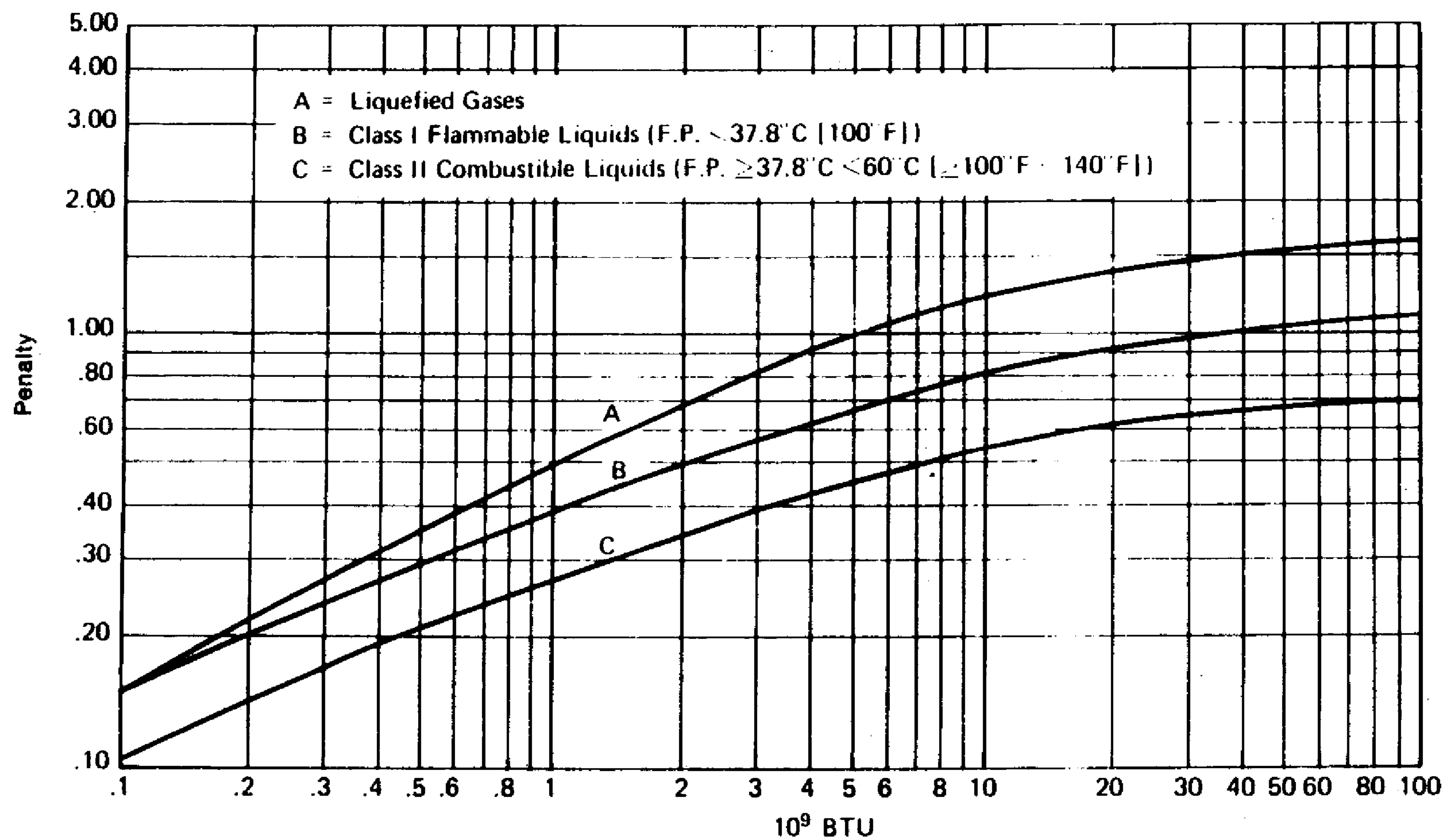


Figure 5 — Combustible Solids in Storage

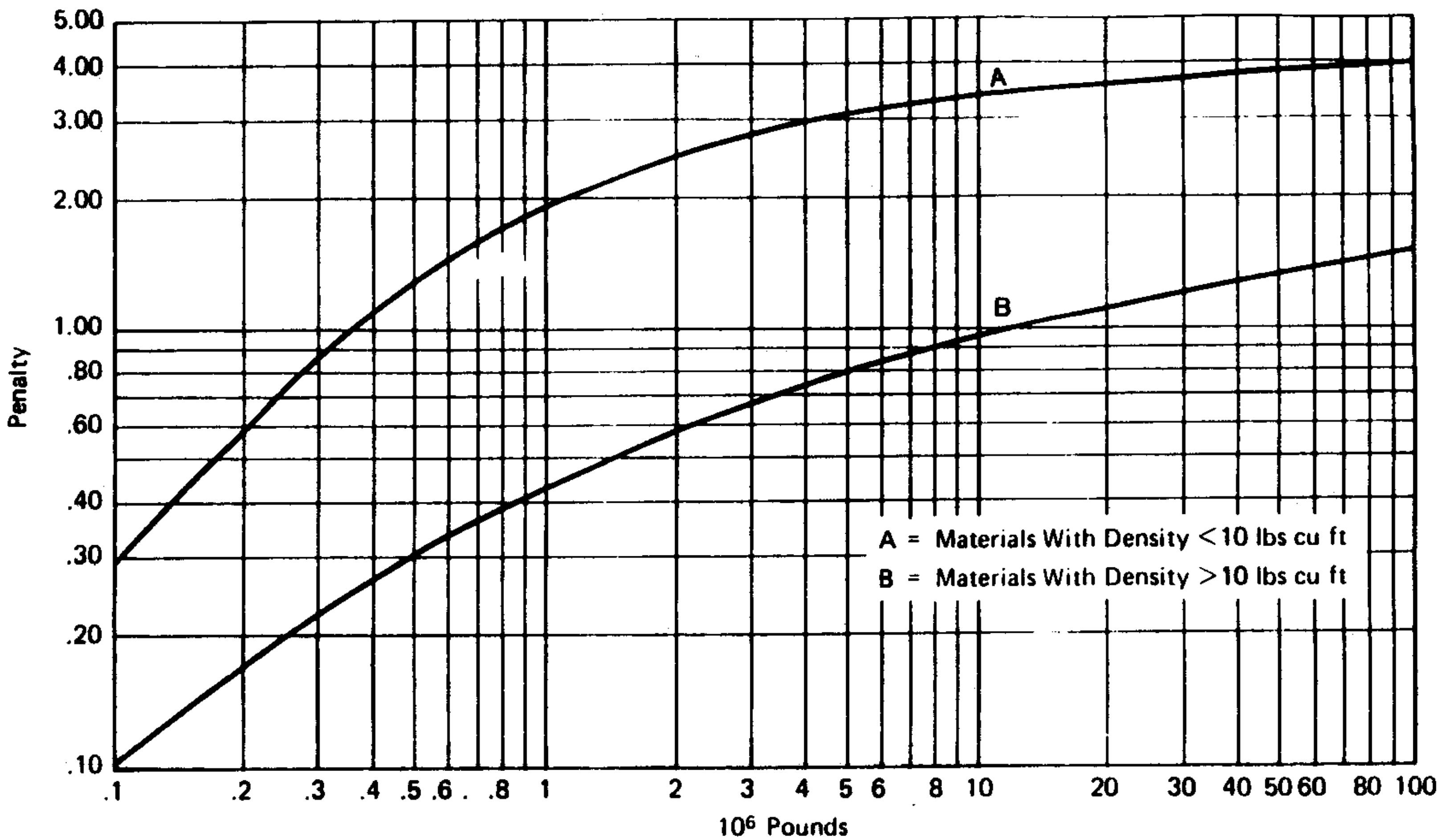


Figure 6 — Fired Equipment Penalty (When Located in Process Plant)

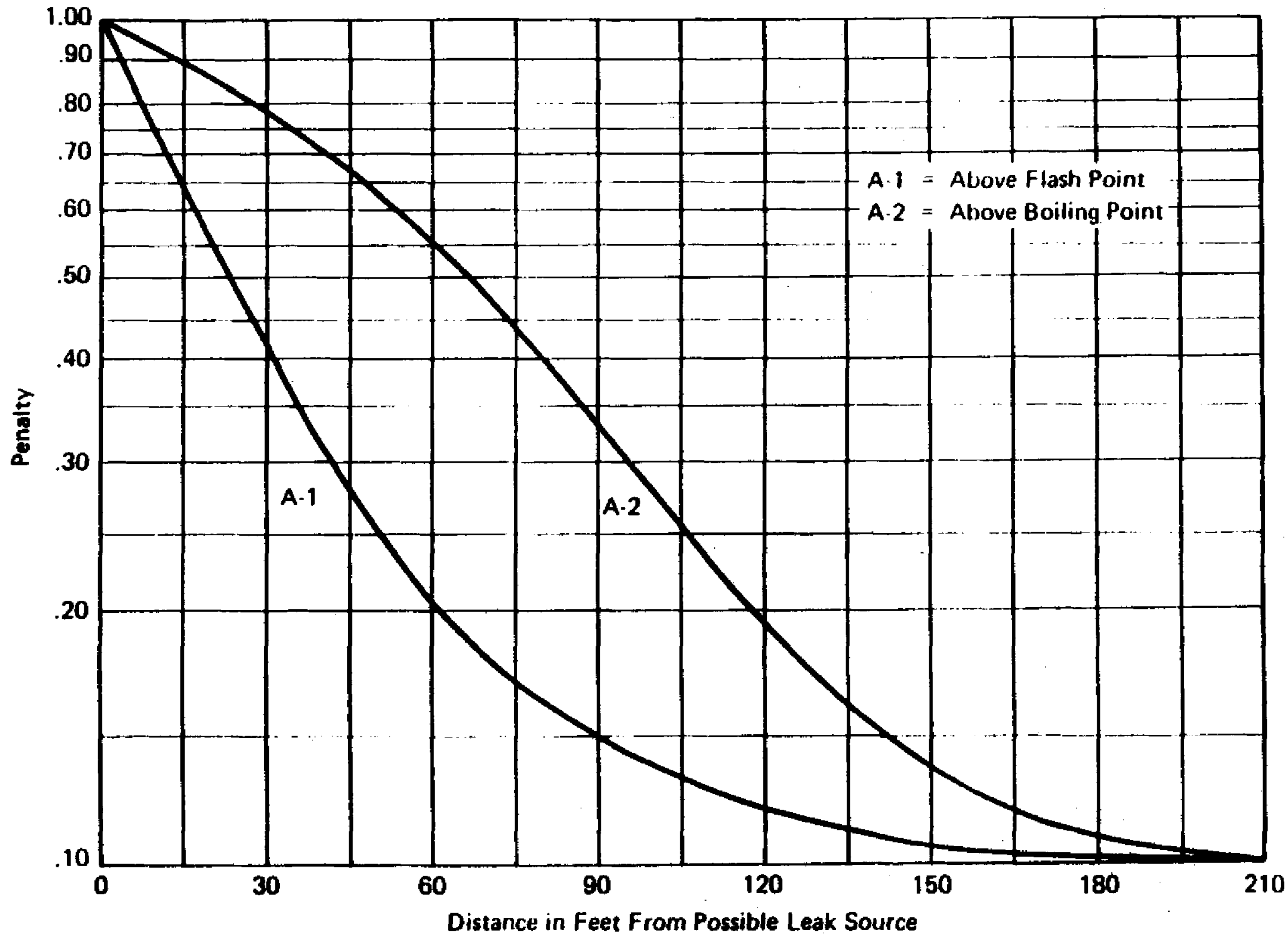


Figure 7 — Damage Factor

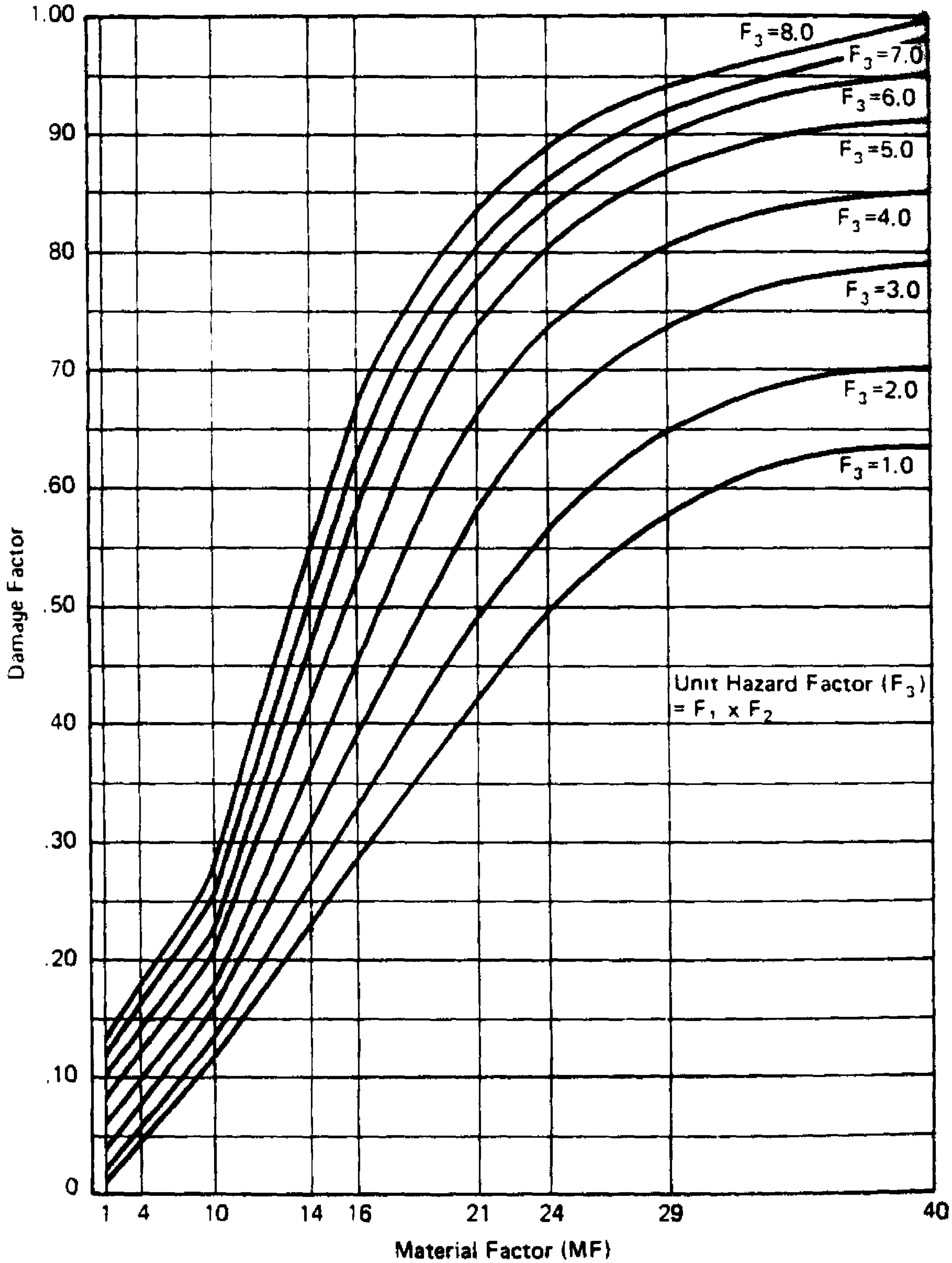


Figure 8 — Area of Exposure

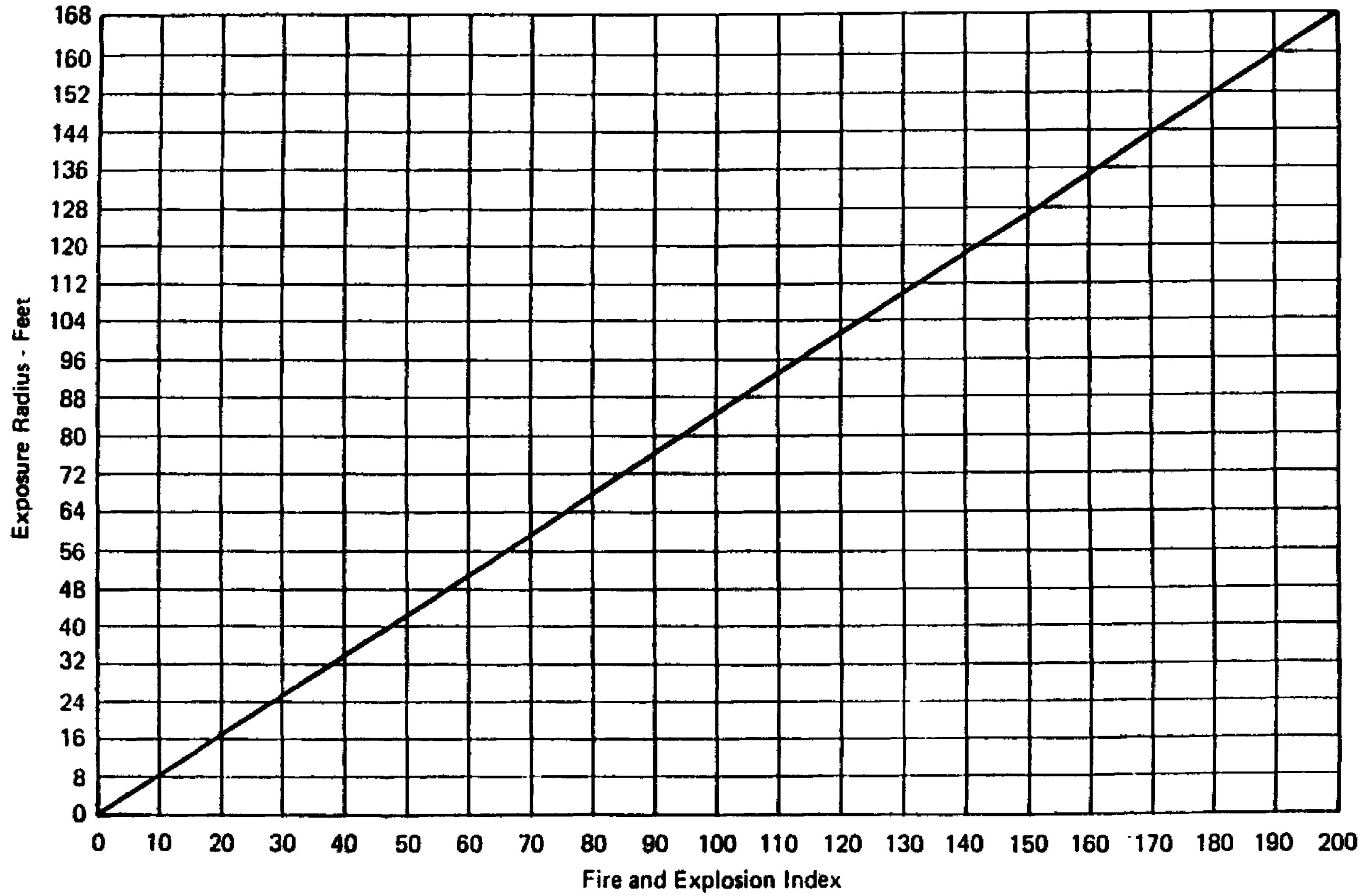
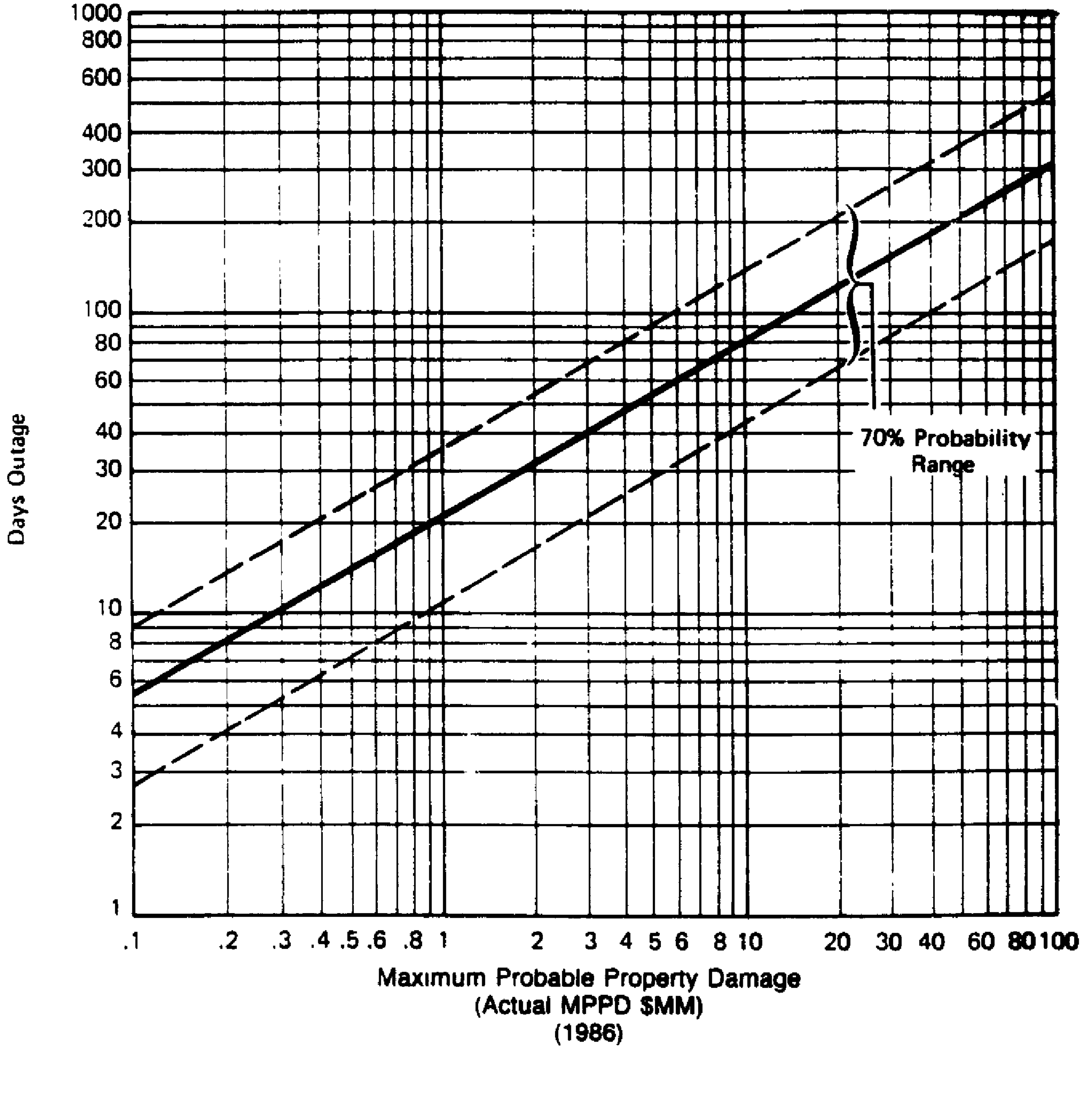


Figure 9 — Maximum Probable Days Outage (MPDO)



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